

Carbon Dioxide: What, Why, How?

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What is CO₂?

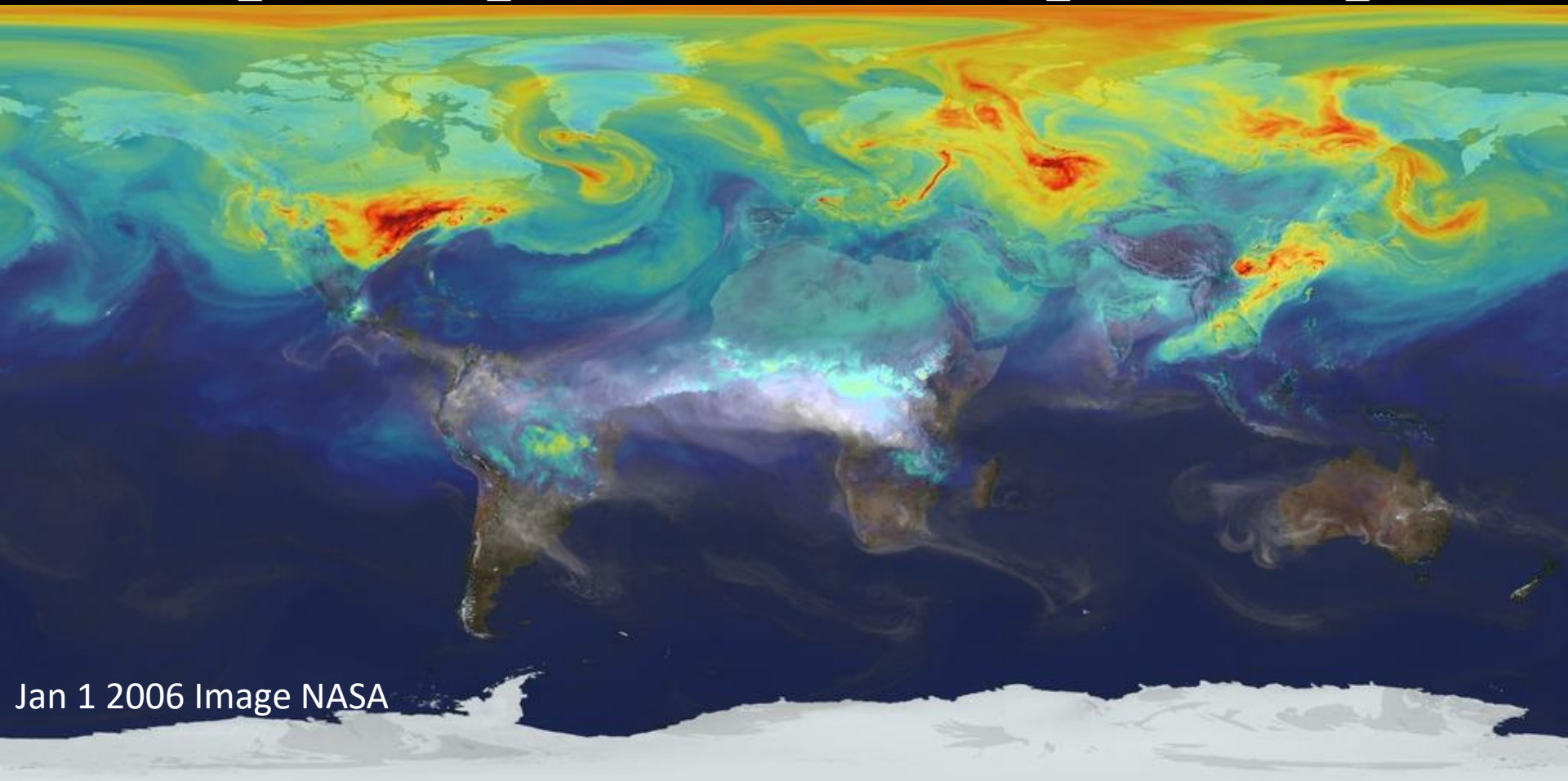
Why do we care about it?

How did it change in the past?

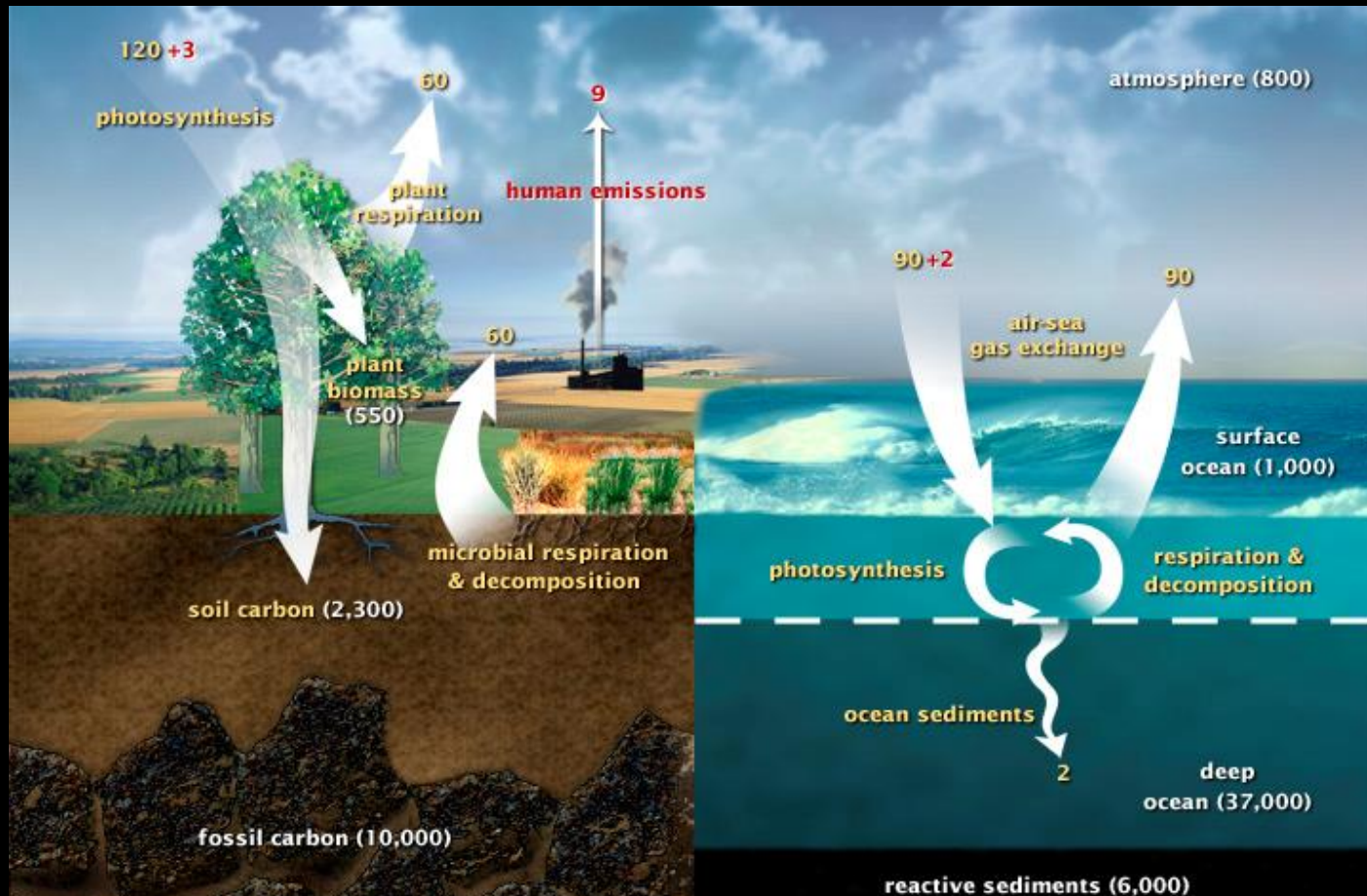
How is it changing now?

How does it affect Maryland?

CO₂ is a naturally occurring gas that is absorbed by plants and stored as biomass (sugars) and released when plant biomass is used for energy



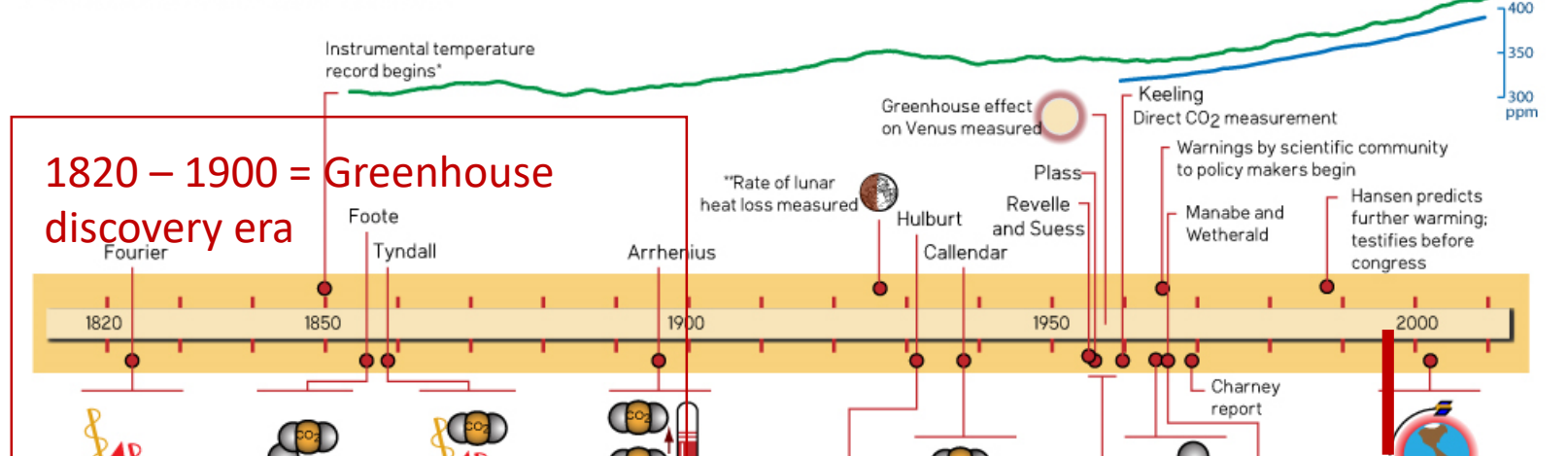
Large fluxes of carbon exchange between atmosphere, land, and ocean, but human emissions create an imbalance leading to accumulation in the atmosphere.



Yellow numbers are natural fluxes, and red are human contributions in gigatons of carbon per year. White numbers indicate stored carbon. ([Diagram](#) adapted from U.S. DOE, [Biological and Environmental Research Information System](#).)

Theory of the greenhouse effect has been well understood for over 100 years.

Milestones in Climate Science



We do not propose that variability in the deep Argentine Basin is necessarily a result of long-term or global climate change. However, high-frequency variability, such as that seen in the Argentine Basin, may indicate that the deep oceans are

www.SkepticalScience.com

Source: All events are from Spencer Weart's
The Discovery of Global Warming
unless noted otherwise:

www.aip.org/history/climate/timeline.htm.

* Temperature graph, GISS

** Pierrehumbert, Principles of Planetary Climate

*** Nature, 15 March 2001



Hulburt calculates
4°C warming from doubling
of CO₂ with H₂O feedback,
and refutes Angstrom



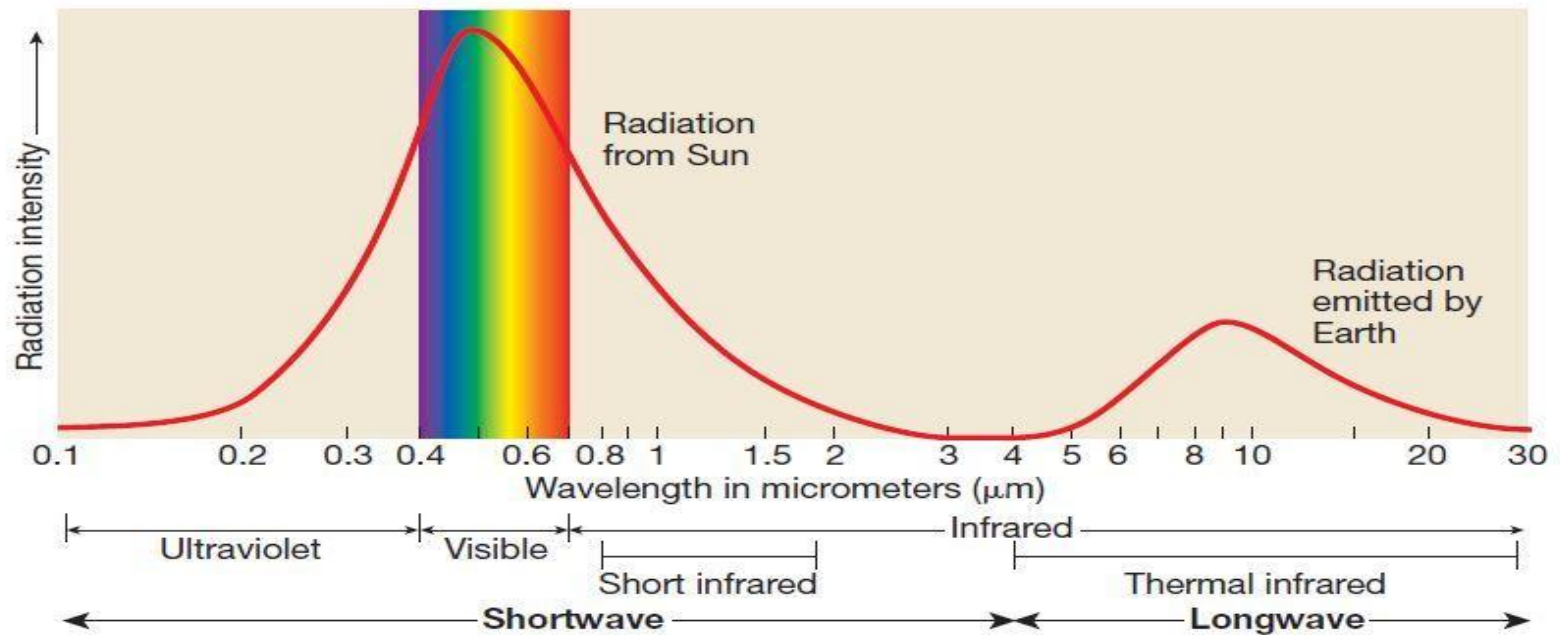
CO₂ sources identified.
Models describe Earth systems,
feedbacks, carbon cycle and climate



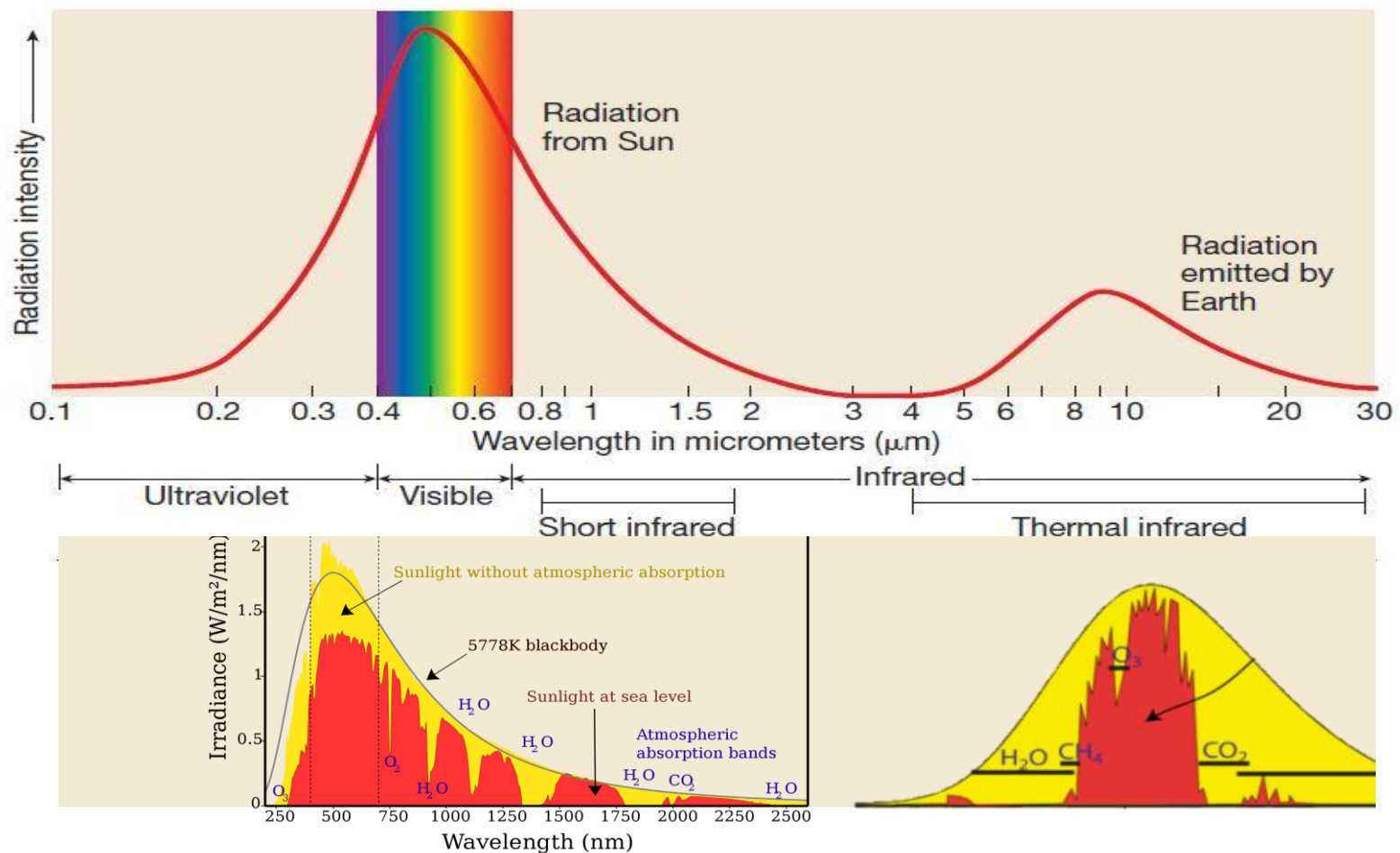
Earth's entire
climate



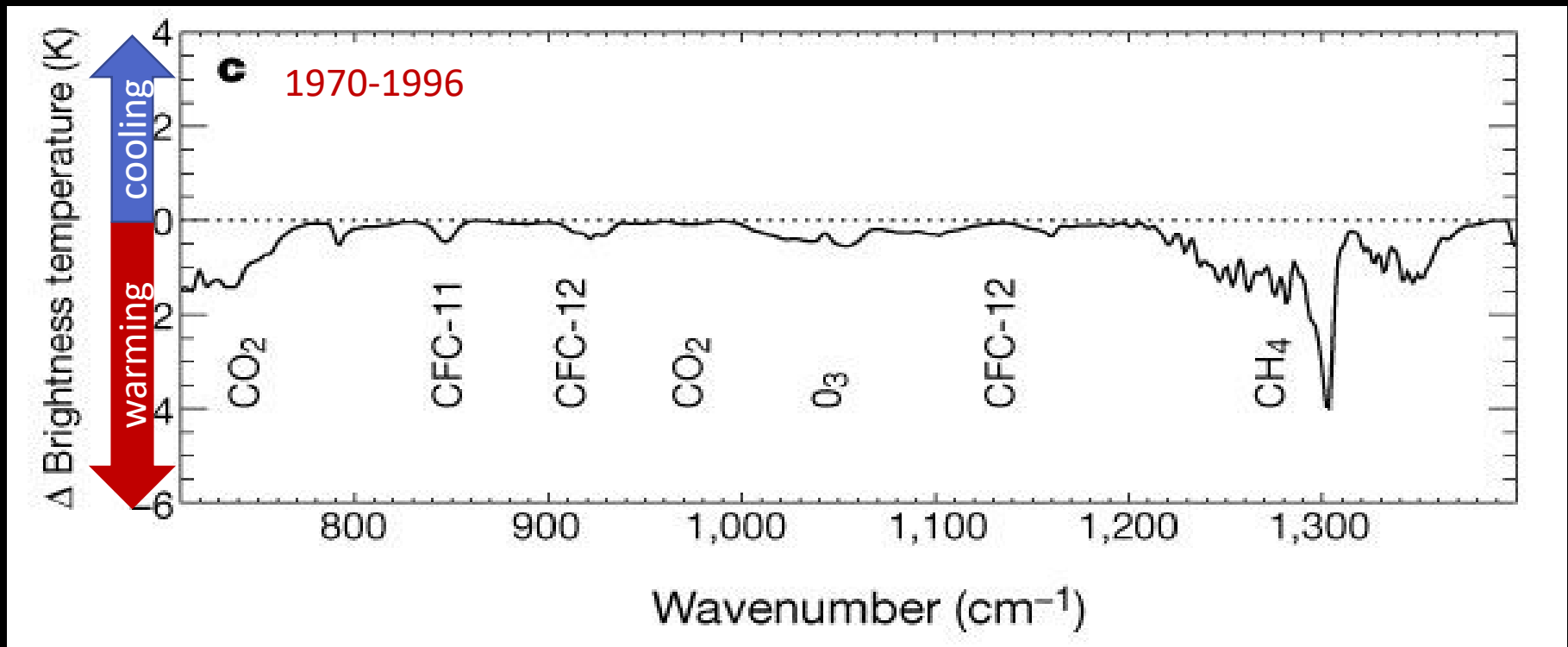
Because the sun is hot, it produces short wavelength energy.
Because the earth is cool, it produces long wavelength energy



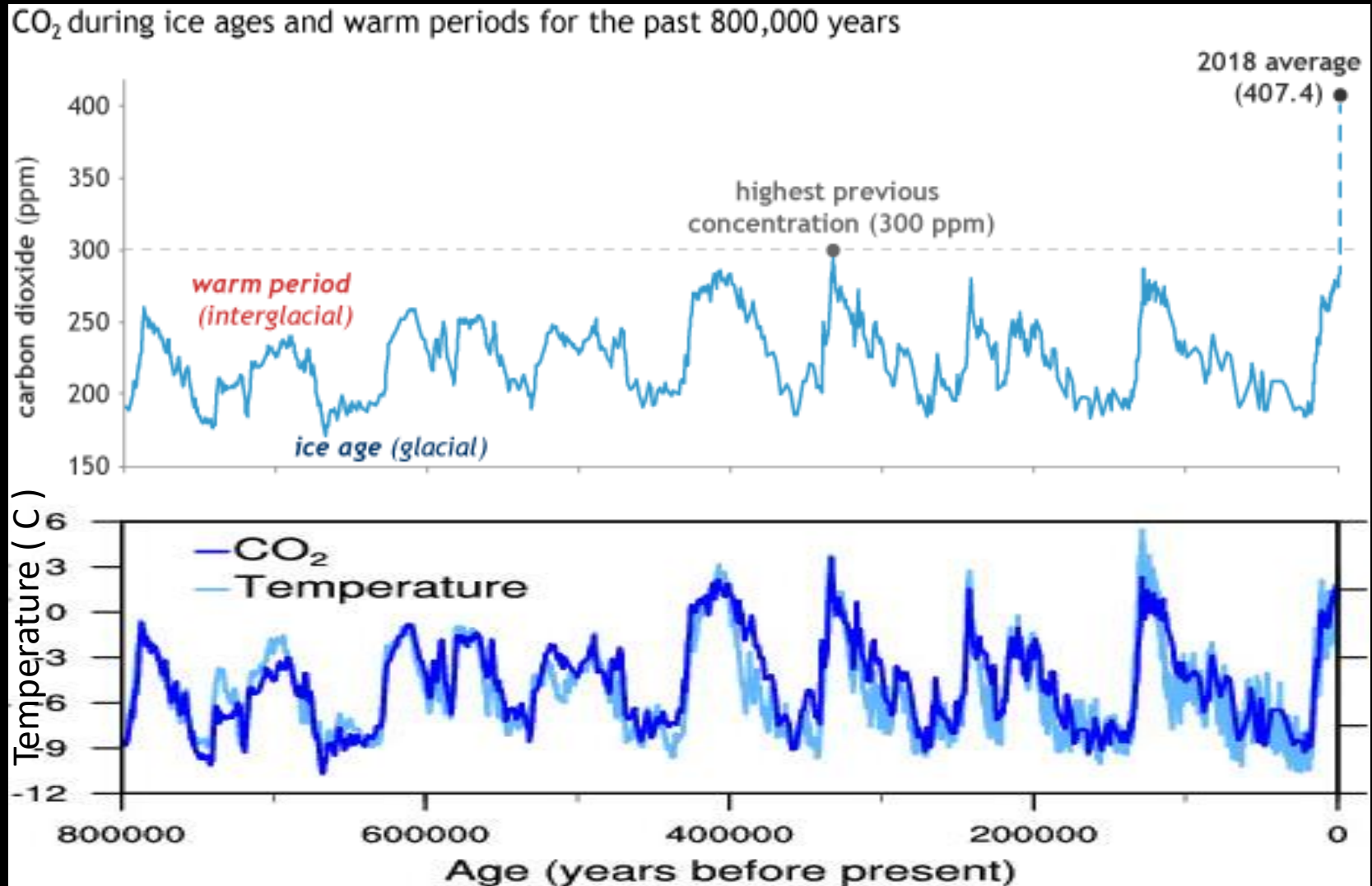
Solar wavelength energy is not absorbed in the atmosphere by CO_2 (much).
Earth wavelength energy is absorbed by CO_2 (in a gap where water vapor is not active).



Satellite observations comparing 1970 to 1996 show warming from more longwave absorption consistent with theory.

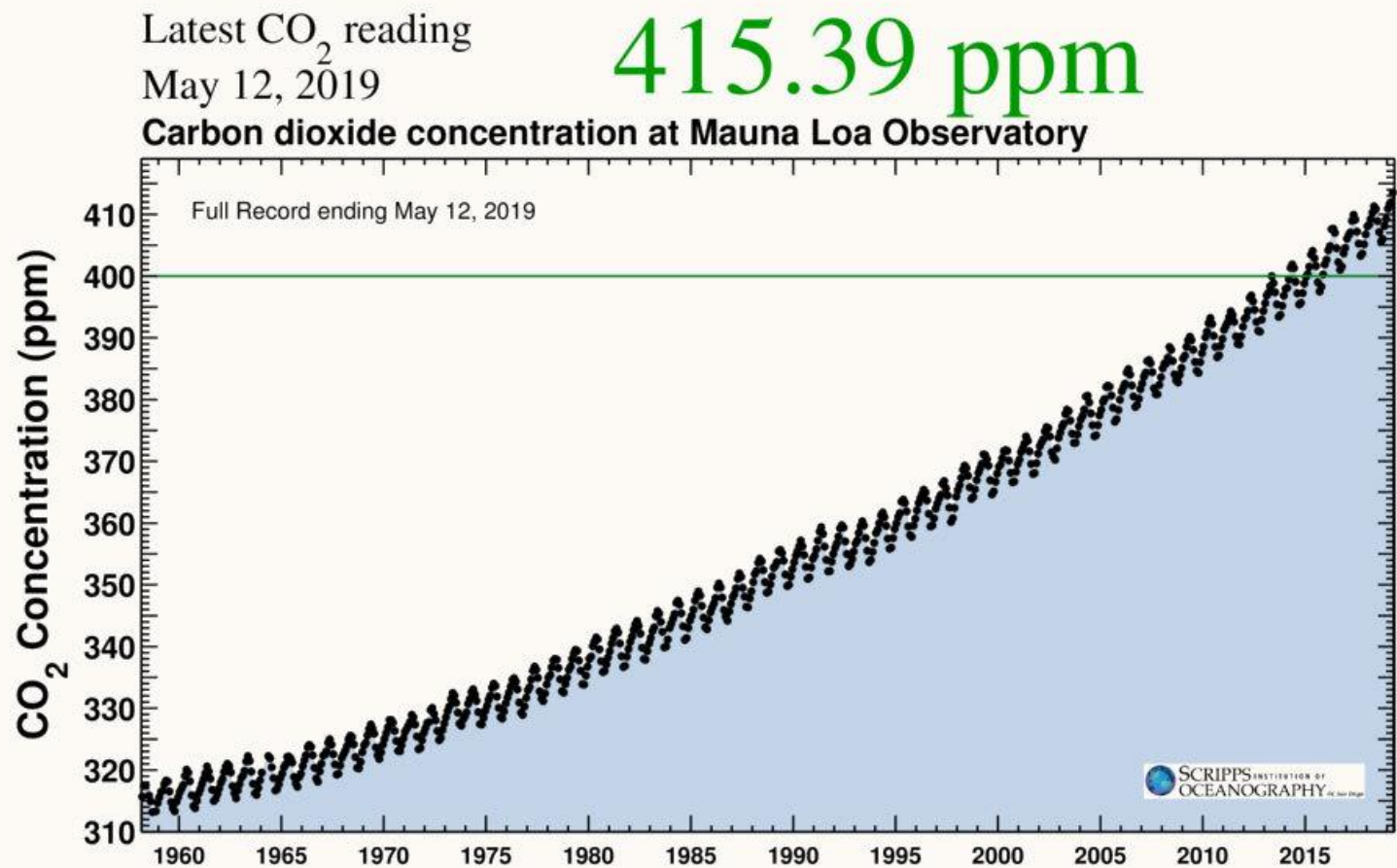


In the past, glacial and interglacial CO₂ and temperature varied together

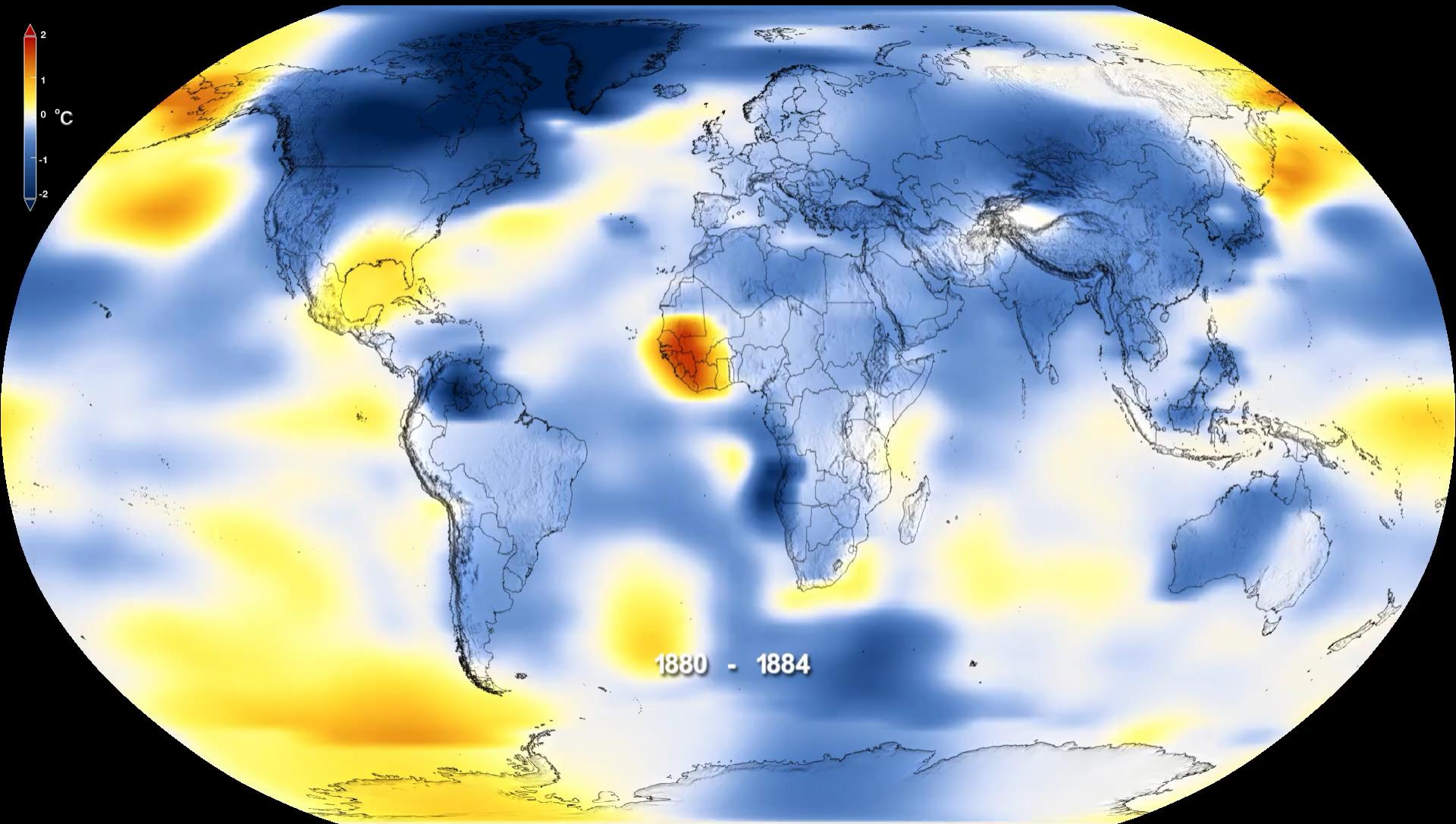


(Graphs by Robert Simmon, using data from [Lüthi et al., 2008](#), and [Jouzel et al., 2007](#).)
<https://earthobservatory.nasa.gov/features/CarbonCycle>

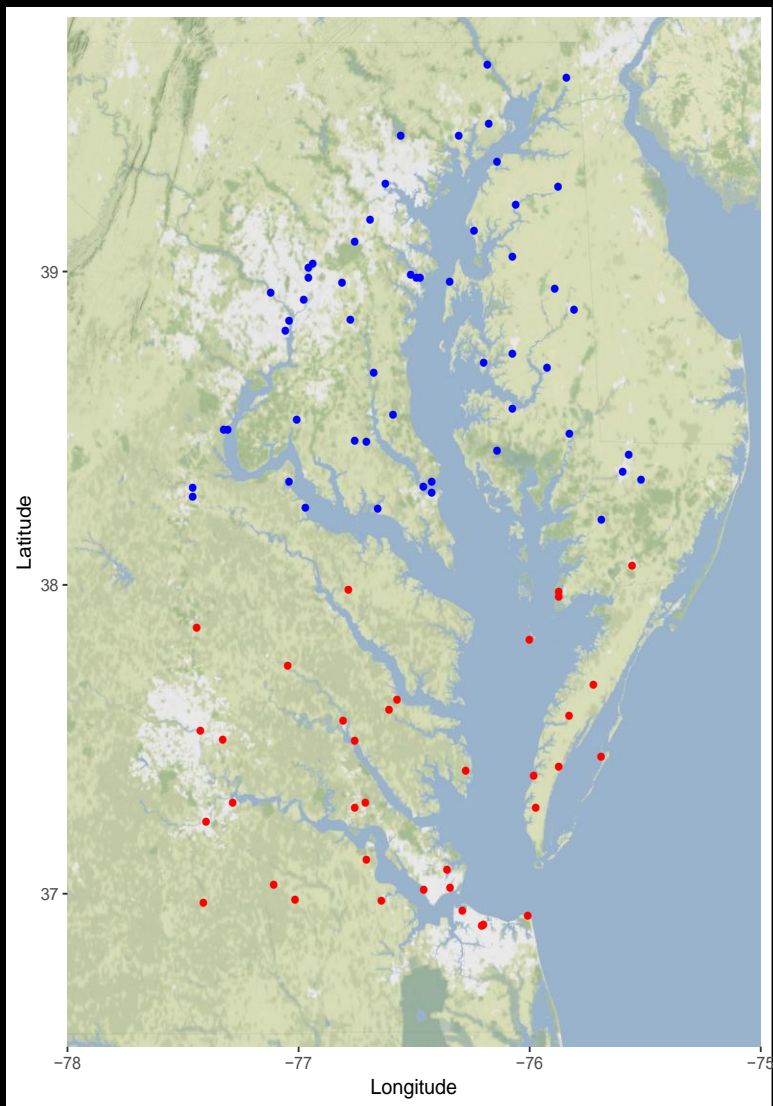
Humans are increasing atmospheric carbon dioxide rapidly.



Globally temperatures have risen sharply from 1880 to 2018



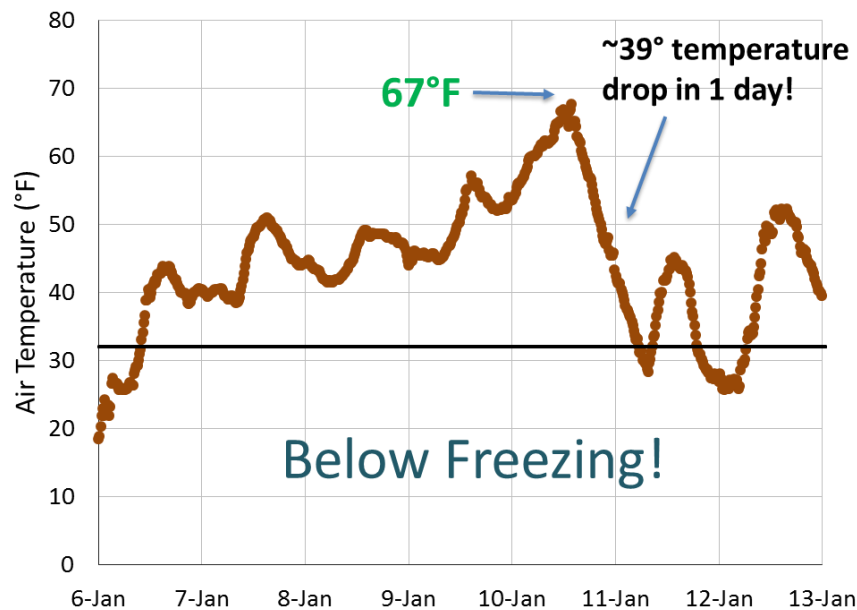
146 weather stations examined in the Chesapeake Bay nearshore region.



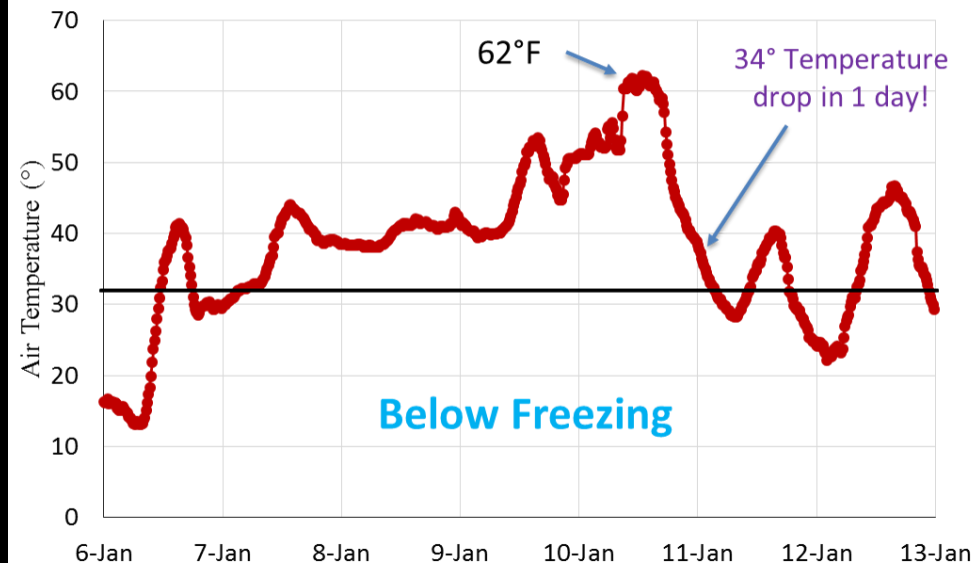
Why Extremes?

- Climate is not weather... But climate extremes are measures of changing weather.
- Organisms, feel variability, highs, and lows (not annual means).
- Helpful in understanding environmental boundary changes, thresholds, tipping points...

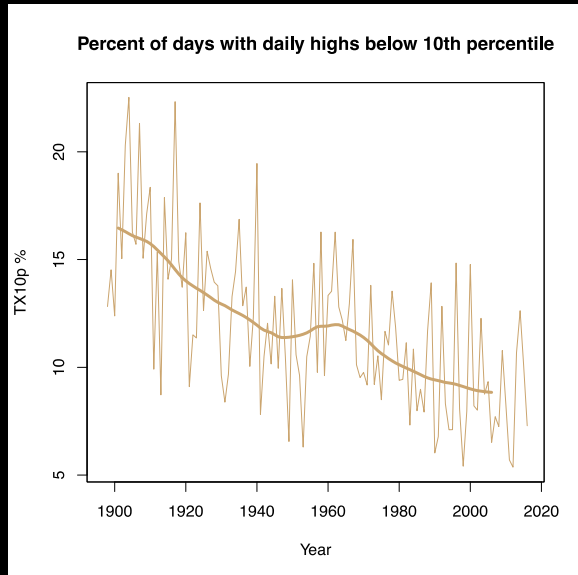
Air Temperature at Taskinas Creek



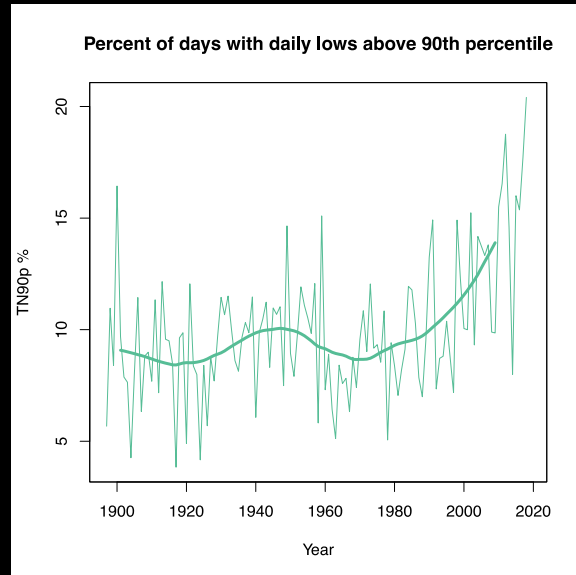
Air Temperature at Jug Bay, MD
from Jan. 6 to Jan 12, 2016



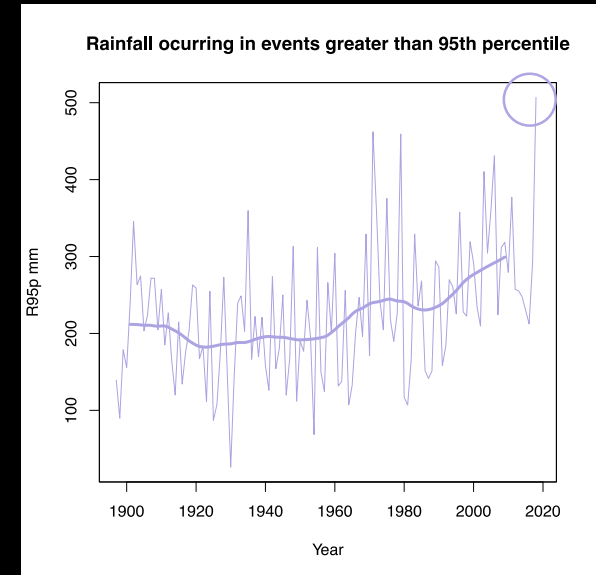
What changes were observed over the past century for MD?



Number of cold days
decreased (10th
percentile)



Number of warm spells
(especially nighttime)
increased (90th
percentile)



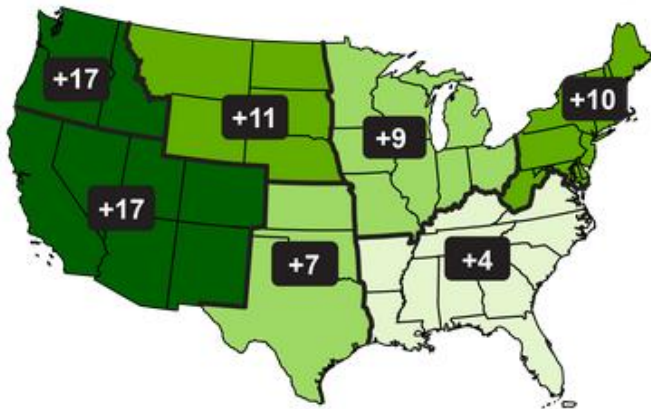
Rainfall from heavy
events has increased
(top 5th percentile)

Chesapeake Bay area is not like the Northeast, or the Southeast, or like Maryland in general.

24 day increase in growing season length over past century.

2017 National Climate Assessment Growing Season Length change over 100 years

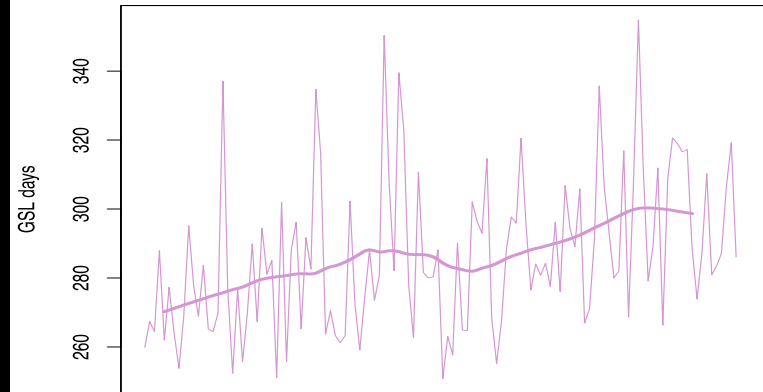
(a) Observed Increase in Frost-Free Season Length



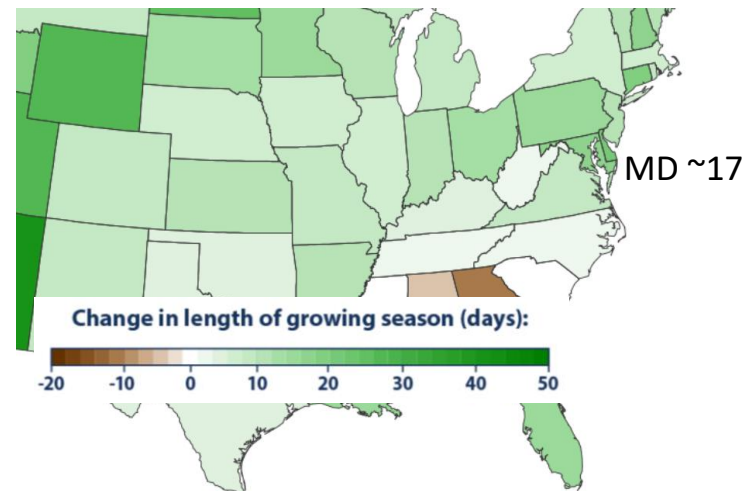
Change in Annual Number of Days

Color	Change in Annual Number of Days
Light Green	0-4
Medium Green	5-9
Dark Green	10-14
Very Dark Green	15+

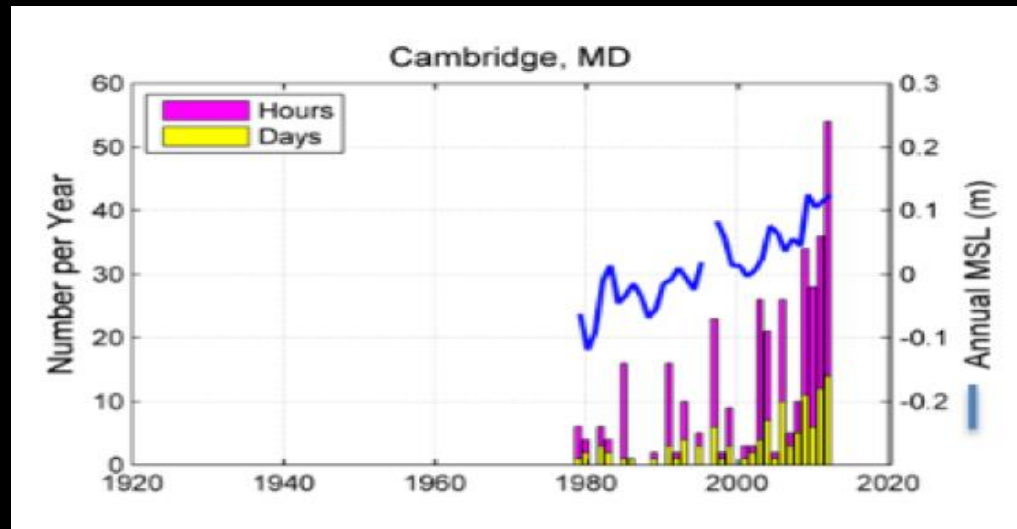
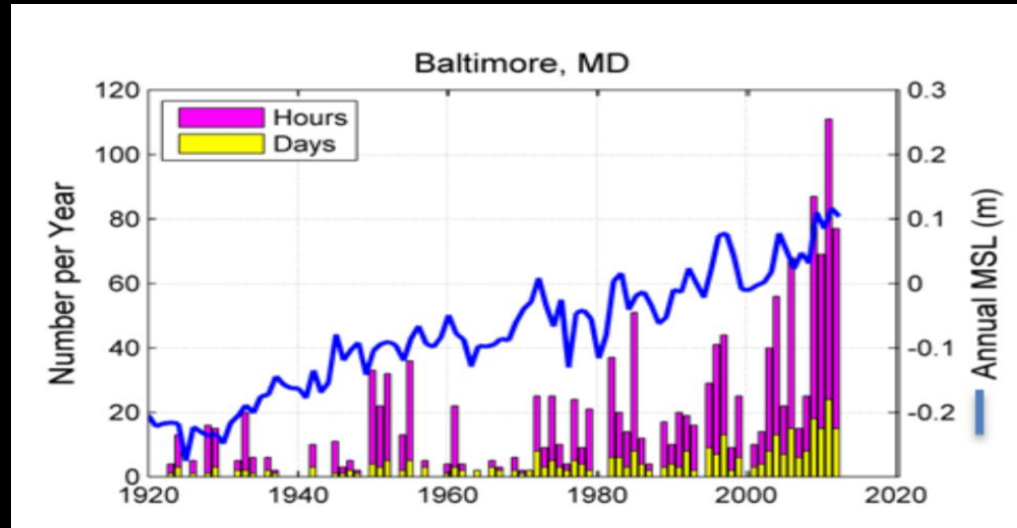
Growing Season Length



State level Analysis Kunkel, 2016



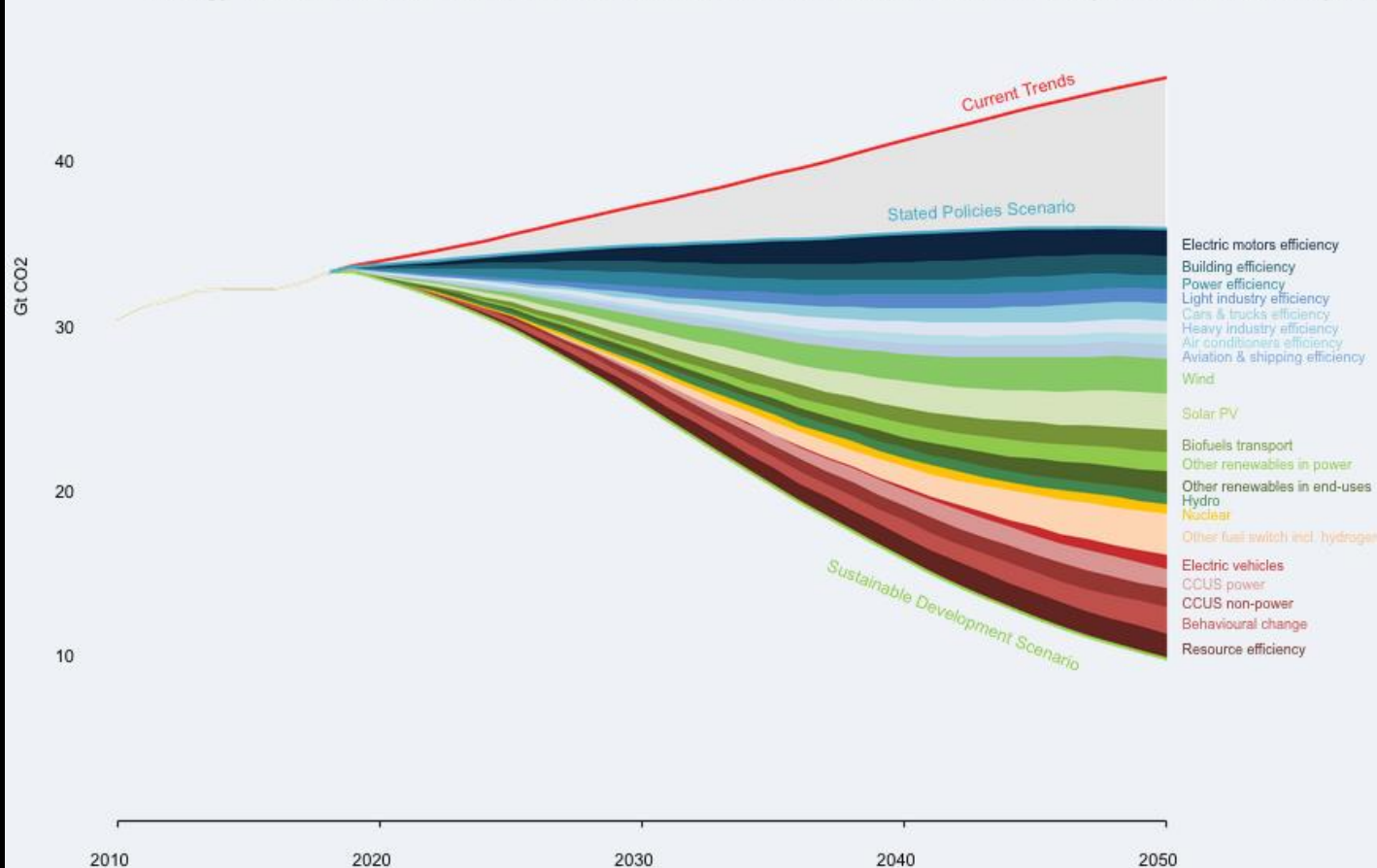
Nuisance flooding (more than 1.5 feet above high water) is increasing rapidly.



There are paths forward...

World Energy Outlook 2019 highlights deep disparities in the global energy system

Energy-related CO2 emissions and reductions in the Sustainable Development Scenario by source



put the world on a path to a secure and sustainable

<https://www.iea.org/weo2019/>



Annual average temperatures for Maryland from 1895-2018 using data from NOAA.